Vitamin C content and sensorial properties of dehydrated carrots blanched conventionally or by ultrasound

Running title: **Vitamin C and sensorial properties of dehydrated carrots**

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ABSTRACT

Vitamin C content and sensorial properties have been evaluated in air-dried carrots previously subjected to different ultrasound (US) or conventional blanching pretreatments. In addition, mass spectral fingerprints obtained by the Headspace ChemSensor System have been evaluated for the first time for classification of carrots according to their processing. Conventional blanching treatments at high temperature gave rise to carrots with retention of vitamin C in the range 37.5-85%, whereas carrots blanched conventionally at 60°C and by US-probe at temperatures up to 60 and 70°C showed vitamin C retention values lower than 4%. Regarding sensorial analysis of rehydrated carrots, US-pretreated samples presented acceptable quality, and no statistically significant differences with respect to conventionally blanched carrots, were detected. In spite of this, differentiation of samples processed under comparable intensity conditions and/or with similar composition was possible from their mass spectral fingerprints after chemometric data analysis.

Keywords:

Dehydrated carrot, blanching, ultrasound, vitamin C, sensorial properties, ChemSensor (MS-electronic nose), mass spectrometry, classification.

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1. Introduction

Carrot (*Daucus carota* L.) is considered one of the vegetables whose consumption, both fresh and processed, has increased over the past years due not only to the nutritional and health benefits this vegetable provides, but also to the introduction of new carrot-derived products (Alasalvar, Grigor, Zhang, Quantick & Shahidi, 2001). In addition, its pleasant flavour is one of the main reasons for its acceptance by consumers; volatiles (mainly terpenes and sesquiterpenes) and sugars being the main compounds that account for the distinctively carrot-like flavour (Alasalvar et al., 2001).

Among the different processes that can be applied to fresh carrot to obtain a product with longer shelf life and/or new characteristics, dehydration by hot-air is probably the most popular (Prakash, Jha & Data, 2004). While the shelf-life might be increased up to one year after dehydration, the quality of dehydrated vegetables might also be negatively affected as compared to that of fresh foodstuff (Negi & Roy, 2001).

Apart from drying conditions (temperature, air-rate, etc), other previous and subsequent sample treatments might affect the quality of the final product (Negi & Roy, 2001). In this respect, blanching is one of the most commonly used pre-treatments to inactivate the enzymes responsible for quality deterioration of processed carrots and it can be carried out under high temperature (Shivhare, Gupta, Basu & Raghavan, 2009) or low temperature (Mohamed & Hussein, 1994) conditions. However, similarly to other thermal processes, blanching and drying have been described to affect several nutritive and bioactive compounds of vegetables including, among others, their vitamin C content (Drake, Spayd & Thompson, 1981). Moreover, both processes can also modify the quality of carrot flavour as a consequence of changes in volatile and sugar profile after these operations (Shamaila, Durance & Girard, 1996; Soria, Sanz & Villamiel, 2008).

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Application of alternative blanching methods and/or optimization of drying conditions may result in processed carrots with better flavour, nutritive and bioactive characteristics. Ultrasound (US) blanching has recently emerged as a pretreatment with positive results on the effective water diffusivity of fruits mainly processed by osmotic dehydration (Fernandes, Rodrigues, Law & Mujumdar, 2011). In the case of carrots, hardly any research has been carried out on the potential of US as an alternative to conventional blanching. Rawson, Tiwari, Tuohy, O'Donnell and Brunton (2011) reported higher retention of carotenoids and polyacetylenes in dried carrots subjected to a pre-treatment with a US probe (10 min under pulsed mode) than in dried carrots blanched at 80°C for 3 min. More recently, Gamboa-Santos, Montilla, Soria and Villamiel (2012) have compared the effect of different conventional blanching methods (water and steam water) and US pre-treatments on enzyme inactivation and leaching losses in carrots. Samples blanched for 10 min by US-probe with generation of heat (temperature up to 60 ºC) showed similar characteristics to those conventionally treated at 60 ºC for a longer time (40 min).

Carrot aroma is generated by a number of volatile compounds of different functionality usually present at very low concentrations; relative volatile composition being dependent on carrot variety, harvesting conditions, pre-processing, processing and storage conditions, etc (Soria et al., 2008). Carrot volatiles have also been described to be highly correlated with different sensory attributes such as odour, taste and aftertaste and with consumer liking (Varming et al., 2004).

Although the common approach for carrot classification according to its volatile composition usually consists of the application of different fractionation techniques for isolation/preconcentration of volatiles previous to their GC-MS analysis (Shamaila et al., 1996; Soria et al., 2008), new methodologies based on direct sampling-mass

spectrometry (DS-MS) have been recently reported for this purpose (Marsili, 2011; Peña, Cárdenas, Gallego, & Valcárcel, 2002). In DS-MS, headspace volatiles sampled directly into the mass spectrometer give rise to a characteristic chemical fingerprint (mass spectrum corresponding to the global volatile profile) for every sample. The use of chemometrics for interpretation of patterns from these multivariate data allows fast and precise classification of samples according to different criteria. Thus, DS-MS has been used for classification of different olive oil classes (Peña, Cárdenas, Gallego, & Valcárcel, 2002) and of wines (Dirinck, Van Leuven, & Dirinck, 2006), among others. Regarding carrots, this methodology has only been applied for discrimination of diseases of stored carrots (Vikram, Lui, Hossain, & Kushalappa, 2006), and no study has yet addressed the application of DS-MS for classification of carrots according to their processing. Advantages of this methodology include minimal sample preparation and high throughput as no prior chromatographic separation is required.

In view of the studies cited above, the main objectives of the present work were: (i) the evaluation in hot-air dried carrots of changes in vitamin C retention and in sensorial properties associated with a previous treatment by US or conventional blanching; (ii) the study of mass spectral fingerprints obtained by the Headspace ChemSensor System (MS-electronic nose) for classification of carrot samples according to their processing.

2. Materials and methods

2.1. Sample preparation

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115 Fresh carrots (*Daucus carota* L. var. Nantesa) were taken from a single batch
116 that was purchased at one time in a local market in Madrid (Spain). Carrots were stored
117 at 4°C for less than a week until processing. Carrots were properly washed in tap water
118 to remove external impurities. Then, samples were cut into slices of 24 mm diameter
119 and 4 mm thickness and as minced carrots (1-2 mm).
120
121 *2.2. Blanching*
122
123 Table 1 summarizes all conventional and US blanching treatments carried out on
124 carrot samples. Processing conditions and sample geometry were chosen on the basis of
125 optimal results in terms of enzyme inactivation and leaching losses previously reported
126 by Gamboa-Santos et al. (2012).
127
128 2.2.1. Ultrasound treatments
129 For US treatments, samples of 40 g were placed into 250-mL Erlenmeyer flasks
130 filled with 200 mL of distilled water and were sonicated using an ultrasonic system (450
131 Digital Sonifier, Branson Ultrasonics Coorporation, Danbury, CT, USA). This sonicator
132 was equipped with a temperature sensor and a tip of 13 mm diameter directly attached
133 to a disruptor horn (20 kHz, 400 W full power) which was immersed 2 cm in the liquid.
134 Experiments were carried out with generation of heat: US blanching for 10 min at
135 temperatures up to 60°C (USP60-10), and for 15 min at temperatures up to 70°C
136 (USP70-15). The ultrasonic density, calculated according to Jambrak, Mason, Paniwnyk
137 and Lelas (2007), was 0.26 W/cm^3.
138
139 2.2.2. Conventional treatments

Using the same carrot - distilled water ratio as above mentioned, carrot samples were subjected to blanching with boiling water for 1 min (CB-1), with water at 95°C for 5 min (C95-5) and at 60°C for 40 min (C60-40) using a hot-plate with temperature control (IKA RCT Basic Labortechnik, Staufen, Germany). Carrot sample CS-2 was pretreated by steam blanching for 2 min using an autoclave (CERTOCLAV CV-EL GS, Austria) operating under atmospheric pressure conditions.

All assays (US and conventional) were performed in duplicate. After treatments, samples were cooled in an ice-water bath and conveniently drained and dried with absorbent paper to remove the excess of distilled water.

2.3. Drying procedure

In order to evaluate the contribution of air-drying to changes in bioactivity and sensory properties of carrots, additional experiments by convective drying were carried out on samples previously subjected to either conventional or US blanching (Table 1).

Blanched carrot samples (80 g) were dried using a computer controlled (Edibon Scada Control and Data Acquisition Software) air tray-dryer (SBANC, Edibon Technical Teaching Units, Spain). This system consists of three main sections: (i) fan unit with control of the air-flow rate, (ii) control of temperature (seven thermo-hygrometers, ST1-ST7) and (iii) drying compartment (load cell with four drying trays). ST7 was chosen as the process temperature since it was the wet bulb closest to the samples. ST7 registered a temperature of 46 ºC by setting the resistance thermometer at a temperature of 60 ºC. The air-flow was parallel to the samples and the air-rate was selected with the AVE sensor at 4.9 m/s. During the drying process, the weight of the

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164 samples was automatically monitorized by using the load cell of the system. Minced
165 carrots were dried for 7 h and sliced carrots for 9 h.
166 The dry matter (DM) content of carrots was gravimetrically determined by
167 drying the samples in a conventional oven at 102 ºC until constant weight, according to
168 the AOAC method (950.01, 1990). After drying, all samples presented DM contents
169 within the range 85-89%.
170
171 *2.4. Determination of vitamin C*
172
173 The procedure employed to determine total vitamin C (ascorbic acid plus
174 dehydroascorbic acid) was the reduction of dehydroascorbic acid to ascorbic acid, using
175 D,L-dithiothreitol as reducing reagent (Plaza, Sanchez-Moreno, Elez-Martínez, de
176 Ancos, Martín-Belloso & Cano, 2006). Carrot extracts were prepared by adding 12.5
177 mL of 0.4% oxalic acid to 0.25 g of carrot samples and homogenizing for 1 min at
178 13500 rpm using an Ultra-Turrax T-25 homogenizer (IKA Labortechnik, Janke &
179 Kunkel, Saufen, Germany). Oxalic acid was used to inhibit further degradation of
180 vitamin C (Erle, 2001). After addition of 2.5 mL of a 5 mg/mL solution of D,L-
181 dithiothreitol, carrot extracts were kept at room temperature in the darkness for 30 min.
182 Once the volume of the slurries was made up to 25 mL with Milli-Q water, they were
183 centrifuged at 3200*g* for 5 min. The supernatant was filtered through 0.45 μm syringe
184 filters. Carrot extracts were made in duplicate.
185 Total vitamin C content of carrots was determined by liquid chromatography
186 with diode array detector (RP-HPLC-DAD) on an Agilent Technologies 1220 Infinity
187 LC System – 1260 DAD (Boeblingen, Germany). The separation of vitamin C was
188 carried out with an ACE 5 C_{18} column (ACE®, UK) (250 mm, 4.6 mm i.d., 5 μm)

189 thermostated at 25 °C, using 5 mM KH_2PO_4 at pH 3.0 as the mobile phase. Elution was
190 done under isocratic conditions at a flow rate of 1 mL/min for 10 min. Injection volume
191 was 20 μL and data acquisition and processing were performed using the Agilent
192 ChemStation software (Agilent Technologies, Germany).

193 Quantitation was performed by the external standard method, using a
194 commercial standard of ascorbic acid (Sigma) in the range 0.3-50 mg/L. Determination
195 coefficient obtained from this calibration curve, which was linear over the range
196 studied, was R^2 = 0.999. Chromatographic repeatability (*n*=5) and method repeatability
197 (*n*=2) were estimated and the relative standard deviation (RSD) calculated was below
198 3%. Results were expressed as milligrams of total vitamin C per 100 g DM.

199 Data were subjected to analysis of variance (Fisher's least significance
200 difference (LSD) test) by applying the Statgraphics 4.0 program (Statistical Graphics
201 Corporation, Rockville, Md) for Windows.

202

203 *2.5. Sensory evaluation*

204

205 After drying, carrot samples were rehydrated in boiling water for 10 min using a
206 sample:water ratio of 1:30 (Prakash, Jha & Data, 2004). The sensory analyses of these
207 samples were carried out by a taste panel of 14 semi-trained judges who were
208 familiarized with samples, attributes and their definitions during two orientation
209 sessions.

210 A triangle test procedure (ISO Standard 4120) was followed. Panellists were
211 presented with 2 groups of 3 samples each, distributed so that in each group 2 samples
212 were the same and another was different in a randomized order. Panellists were asked to
213 identify the odd sample, paying special attention to the taste and texture. Rehydrated

carrot samples were also evaluated in a hedonic test. Two different sessions were performed: D-C60-40 and D-USP60-10 carrot samples were coded and presented at random order to the panellists in the first session and D-CS-2, D-CB-1, D-C95-5 and D-USP70-15 carrot samples in the second. The panellists were asked to indicate their preference for each sample, mainly based on texture and taste. A balanced 8-point hedonic rating was employed for all the attributes evaluated, where 1 denoted "like very much" and 8 indicated "dislike very much" (Sancho, Bota & de Castro, 2002). Similarly to data of section 2.4, overall scores obtained were compared by analysis of variance.

Data were subjected to analysis of variance (Fisher's least significance difference (LSD) test) by applying the Statgraphics 4.0 program (Statistical Graphics Corporation, Rockville, Md) for Windows.

2.6. Discrimination analysis using the ChemSensor System (MS e-nose)

Dehydrated samples were ground and aliquots of 0.3 g of each treatment plus 300 µL of water were placed in a 10 mL vial and were hand-crimper sealed with an inert septum. DS-MS analyses were performed with a ChemSensor 4440B system (Agilent Technologies, Palo Alto, CA, USA), which can be considered as a MS electronic nose. It comprises of two modules. The first one is a 44-vial autosampler for headspace sampling (Agilent HS 7694) that includes an oven to heat the samples and to form the headspace (120 ºC for 30 min), and a six-port injection valve with a 3-mL loop. Helium at 16 psi for 18 s was used for pressurizing the vial. The second module is a quadrupole mass spectrometer detector (MS5973N), operated in full scan mode (*m/z* 50-200) at 1.43 scans/s. The ionization energy was 70 eV. The transfer line, source, and quadrupole temperatures were set at 140, 230, and 150°C, respectively. Data were

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239 acquired and a chemometric analysis was performed using Pirouette data analysis
240 software (v3.11, Infometrix Inc., Bothell, WA).

241 *Chemometric procedures*. Matrix of *m/z* abundances was obtained from mass
242 spectral fingerprints collected for every sample and subjected to statistical analysis.
243 First, an unsupervised technique such as Principal Component Analysis (PCA) was
244 applied in order to reduce the dimensionality of the data matrix and to find internal
245 structures or clustering of data. Later, a supervised technique, Soft Independent
246 Modeling Class Analogy (SIMCA), was used to obtain adequate classification
247 procedures at the 95% confidence level. SIMCA develops principal component models
248 to classify samples into discrete categories. It is based on the concept of proximity, the
249 assumption that if a set of measurements for an unknown sample is very similar to that
250 of a specific group, then the unknown is likely to be a member of that group. Although
251 the ultimate goal of SIMCA is the reliable classification of new samples (i.e.,
252 unknowns), in this study SIMCA was used for discrimination of samples according to
253 their processing. Thus, samples were visually classified by observing its position in the
254 Coomans plot where the multiple thresholds divide the plot space into subregions of
255 membership and not: a) the sample fits only one pre-defined category (a sample in the
256 NW quadrant is a member only of the *x* axis class, and a sample falling in the SE
257 quadrant is a member only of the *y* axis class); b) the sample does not fit any pre-
258 defined categories (sample in the NE quadrant); c) the sample fits into more than one
259 pre-defined category (sample in the SW quadrant) (Coomans, Broeckaert, Derde, Tassin
260 & Massart, 1984).

261

262 **3. Results and discussion**

263

264 *3.1. Effect of processing conditions on vitamin C*

265

266 The retention of vitamin C is often used as an estimation of the overall
267 nutritional quality of food products, particularly, vegetables (Goula & Adamopoulos,
268 2006). The losses of this vitamin are mainly attributed to its solubility in water and to its
269 sensitivity to high temperatures and oxidation conditions (oxygen, pH and metal ions)
270 (Davey et al., 2000). Table 2 shows the content of vitamin C (mg/100 g DM) and the
271 corresponding percentages of vitamin retention of the different carrot samples (dried
272 and/or blanched) analysed in the present study. The content of vitamin C of raw carrot
273 was close to data previously reported by other authors (Negi & Roy, 2001; Frias, Peñas,
274 Ullate & Vidal-Valverde, 2010).

275 Considering the effect of blanching, as can be seen in Table 2, the highest
276 content of vitamin C, representing 85% retention of this vitamin, was found in CB-1
277 carrot sample. Frías et al. (2010) reported approximately the same retention level (80%)
278 of vitamin C in samples of carrots subjected to the same blanching conditions. After
279 CS-2 treatment, the percentage of retention was also very high (81%), and no significant
280 differences ($p>0.05$) were found with respect to previous treatment. Drake et al. (1981)
281 studied the influence of blanching method on the quality of selected vegetables and they
282 found that water and steam blanched asparagus and green beans showed similar
283 ascorbic acid concentration. Lin and Brewer (2005) observed in peas that steam
284 blanching resulted in significantly better ascorbic acid retention than treatments with
285 boiling water for equal blanching time. In the case of blanching treatments carried out at
286 95 ºC for 5 min (C95-5) (Table 2), carrots presented a considerable reduction (62.5%) in
287 the content of vitamin C. However, Shivhare, Gupta, Basu and Raghavan (2009),
288 among the different assayed conditions, proposed this combination of temperature and

289 time together with 0.05 N acetic acid solution, as the best blanching treatment of carrots
290 destined to juice elaboration. Lin, Durance and Scaman (1998) reported that blanching
291 of carrots at 90 ºC for 7 min before drying can preserve 57.5% of vitamin C content and
292 Negi and Roy (2001) found 87.6% of retention of this vitamin after blanching of carrots
293 at 95 ºC for 90 s. In agreement with our experimental data, all these results highlight the
294 great influence of small changes in blanching conditions (temperature, time, sample
295 geometry, blanching water:carrot weight ratio, etc) on preservation of vitamin C content
296 of carrots.

297 Regarding low temperature long time (LTLT) conventional blanching
298 treatments, as shown in Table 2, C60-40 assay was the most drastic and resulted in the
299 highest loss of vitamin C. These results could be explained by the noticeable leaching
300 loss associated with long blanching times and/or the sample geometry, since C60-40
301 carrots were minced and presented higher specific surface than the slices used in the
302 other conventional treatments (Table 1). In spite of the mild temperature used (60 ºC),
303 no oxidation of ascorbic acid due to residual ascorbic acid oxidase was suspected since,
304 according to Rayan, Gab-Alla, Shatta and El-Shamei (2011), hardly any residual
305 activity of this enzyme is presented under these experimental conditions.

306 In the case of carrot samples subjected to US blanching (Table 2), the loss of
307 vitamin C was also very high, particularly in the case of USP60-10, which was close to
308 99%, as shown for C60-40 assay. These results are in agreement with the similar losses
309 by leaching of total solids and soluble sugars and with the comparable results on
310 inactivation of peroxidase and pectinmethyesterase previously reported for these
311 samples (Gamboa-Santos et al., 2012). When USP60-10 and USP70-15 samples were
312 compared, no significant differences ($p>0.05$) were found for the retention of vitamin C.

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313 The main mechanism involved in the loss of vitamin C during US blanching
314 treatments might be the formation of microchanels during cavitation which facilitate the
315 transport of food constituents, especially soluble nutrients (Mothibe, Zhang, Nsor-
316 atindana & Wang). In agreement with this, Opalic, Domitran, Komes, Belščak, Horžić,
317 Karlović (2009) reported that prolonged US pretreatment in samples with the same
318 geometry led to a decrease in total phenols and flavonoids as well as in the antioxidant
319 capacity of dried apples.

320 The effect of drying on the retention of vitamin C of the different blanched
321 carrot samples studied was also evaluated (Table 2). Since all samples were dried under
322 the same conditions (46°C; 4.9 m/s), the observed variations in the final content of this
323 vitamin (traces to 18.77 mg/100 g DM), as we have indicated above, were due to the
324 different blanching procedures. The highest retention was found in D-CS-2 and D-CB-1
325 carrot samples; however, D-C95-5 carrot lost most of its content of vitamin C by
326 leaching during blanching and the losses during dehydration were similar to those
327 observed in D-CS-2 and D-CB-1 samples. With respect to the other samples analysed
328 (D-C60-40, D-USP60-10, D-USP70-15), very low amounts of vitamin C were detected
329 after drying since the prior blanching treatments were very severe.

330 The destruction of thermolabile vitamin C during the drying process was mainly
331 due to the effect of drying time, since the temperature of the process was rather mild
332 (46°C). In agreement with this, Mohamed and Hussein (1994) observed that ascorbic
333 acid of carrot was easily damaged by long drying times, whereas carotenoids were more
334 sensitive to drying temperature than to drying time. Negi and Roy (2001) reported 46%
335 of vitamin C retention in carrots blanched at 95°C for 30 s after drying at 65°C whereas
336 Frias et al. (2010) reported retention data of this vitamin within the range 43-50% in

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carrot samples blanched in boiling water (60 s) and subsequently subjected to drying by convection at temperatures of 43-52°C for 6 hours.

3.2. Sensory evaluation

Sensory evaluation of the rehydrated carrot samples was carried out to obtain preliminary information on consumer's preference and product acceptance. Sensory assessment of dried samples was not performed, as Lin et al. (1998) found that colour, appearance, texture, aroma/flavour and overall acceptability of hot air-dried carrot slices were greatly improved when they were rehydrated and, moreover, dried carrots will mostly be consumed in rehydrated form.

In the triangle test, samples D-C60-40 and D-USP60-10 could not be distinguished in relation to the flavour and texture by the sensory panel since only 50% of panellists found the odd sample. The mean overall liking scores of the evaluated samples are shown in Table 3 and, as it can be observed, no significant differences ($p>0.05$) were found between the analysed samples. The score values were within the range 3.7 (close to "like slightly") for D-C60-40 and 3.2 (close to "like moderately") for D-USP60-10 carrot samples. When D-CS-2, D-CB-1, D-C95-5 and D-USP70-15 rehydrated carrot samples were compared in the hedonic scale (Table 3), the liking scores were similar among them and within the rating range "like moderately"- "like slightly", previously mentioned for the remaining samples here evaluated.

The obtained scores could be considered low for a highly appreciated product like carrots, but this fact could be explained considering the unavoidable losses of carbohydrates taking place mainly during blanching. Moreover, changes in volatile composition by evaporation, degradation, leaching and/or formation of new compounds

362 through blanching and processing could also support these results. In agreement with
363 this, Shamaila et al. (1996) reported that blanching exerts a significant negative effect
364 on the sensory attributes of carrots and their overall impression.

365 As it is well-known, carbohydrates together with volatiles are mostly responsible
366 for the pleasant flavour and consumer acceptance of carrots (Alasalvar et al., 2001).
367 Although no significant differences ($p>0.05$) were found, it is remarkable that the
368 sample with the best score (3.0) was that corresponding to steam blanching (D-CS-2),
369 probably due to the fact that this procedure has a lower impact on the losses of
370 carbohydrates and volatiles than the conventional ones (Shamaila et al., 1996; Wang et
371 al., 1997; Gamboa-Santos et al., 2012).

372 In general, the panellists highlighted the difficulty of the test since the assayed
373 samples presented similar attributes and overall quality. Since drying and rehydration
374 were the same in all cases, it seems that differences caused by blanching were
375 minimized during the subsequent steps of processing. Similarly, Lin et al. (1998) found
376 no significant differences in overall acceptability of rehydrated carrots previously
377 blanched (at 90 ºC during 7 min) and processed by air drying, vacuum microwave
378 drying, and freeze-drying; however, differences were found when the non-rehydrated
379 samples were compared.

380 Samples subjected to US blanching prior to drying by convection presented an
381 acceptable quality, similar to that of carrots blanched by different conventional
382 methods. Opalic et al. (2009), in a study on the use of an ultrasonic bath for 9-54 min
383 for blanching of apples before drying, found a decrease in the sensory characteristics
384 with the time of processing. When US were applied to osmotic drying of fruits,
385 consumers preferred these samples because of their high sugar content (Mothibe et al.,
386 2011).

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3.3. Discrimination analysis using the ChemSensor System (MS e-nose)

Mass fingerprints obtained by using the ChemSensor methodology for samples under study (Table 1) were subjected to PCA in order to explore their unsupervised grouping. As shown in Fig 1 (PC1 vs PC2, 87.33% of variance explained), precision of the method was good for all the samples analysed, with scores corresponding to the same treatment being plotted close to each other. Considering the different blanching types assayed, only C60-40 pretreatment and its corresponding dehydrated carrots (D-C60-40) were plotted apart based on their high PC1 scores (> 50). On the other hand, from the similar location in this figure of blanched and their subsequently dehydrated carrots, it can be highlighted the higher impact of blanching conditions over identical dehydration on volatile composition of carrots, particularly for those samples processed under the most energetic conditions.

The scores plot of samples in Fig 1 also shows the coincidence of this classification with their vitamin C content. Thus, samples plotted at the right-bottom of this figure showed very low retention of vitamin C (C60-40, D-C60-40, USP70-15, D-USP70-15, USP60-10, D-USP60-10), whereas samples plotted at the left-top showed high retention of this vitamin (CB-1, CS-2, D-CB-1, D-CS-2, C95-5, DC95-5).

Based on ChemSensor testing using *m/z* intensity results, samples were visually classified by observing its position in Coomans plots. As example, Fig 2 shows some of them. Samples for every category clustered nicely, being this a prior requirement for its classification.

Regarding the effect of blanching in samples not further dried, the pairs of samples CS-2 vs CB-1 (Fig 2a), C60-40 vs USP60-10 (Fig 2b), USP70-15 vs CS-2 and USP70-15 vs CB-1 were clearly classified in the correct class. It is noteworthy that

412 samples subjected to similar blanching (CS-2 and CB-1) were properly separated in the
413 Coomans plot. Similarly, different treatments (C60-40 and USP60-10) which gave rise
414 to the same chemical changes during the leaching of components (Gamboa-Santos et al.,
415 2012) were also correctly classified. Only some comparisons such as the pair USP70-15
416 vs C95-5 (Fig 2c) did not show an evident separation. Thus, whereas the USP70-15
417 samples were properly classified, the C95-5 samples were not, as they were borderline
418 cases lying close to one of the thresholds.

419 When comparing carrots subjected to different blanching treatments and further
420 dried under identical conditions, results were similar to those of non-dehydrated
421 samples: D-CS-2 vs D-CB-1 (Fig 2a'), D-C60-40 vs D-USP60-10 (Fig 2b'), D-USP70-
422 15 vs D-CS-2 and D-USP70-15 vs D-CB-1 were correctly classified, whereas samples
423 D-USP70-15 vs D-C95-5 (Fig 2c') were not properly identified as members of its actual
424 categories. It can be concluded from these results that blanching conditions were the
425 predominant factor affecting the global volatile composition of carrots here analysed, all
426 of them dehydrated under identical experimental conditions. Furthermore, Chemsensor
427 results allowed the differentiation of samples indistinguishable for 50% of the members
428 of the taste panel (Section 3.2; D-C60-40 vs D-USP60-10).

429

430 **4. Conclusions**

431

432 The high solubility in water of ascorbic acid makes the inevitable losses by
433 leaching, associated to any of the blanching treatments assayed, responsible for the
434 reduction to a certain extent of the content of this important vitamin. Taking into
435 account the content of vitamin C, the samples with the highest retention were those
436 subjected to conventional blanching at high temperature and short times. With respect to

samples subjected to US blanching prior to drying by convection, the most striking feature was their acceptable organoleptic quality, similar to that of carrots blanched by different conventional methods. The statistical analysis of mass spectral fingerprints gathered by the ChemSensor methodology allowed the differentiation of samples with a similar composition and/or blanching treatments, and indistinguishable for a taste panel of semi-trained judges. These results underline the usefulness of ChemSensor as a tool to classify processed carrot samples.

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Figure captions:

Fig. 1. Principal component biplot of mass spectral fingerprints corresponding to carrot samples under analysis.

Fig. 2. Coomans plots. For identification of samples, see Table 1.

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